

Teaching Disciplinary Literacy to Adolescents: Rethinking Content-Area Literacy

TIMOTHY SHANAHAN

CYNTHIA SHANAHAN

University of Illinois at Chicago

In this article, Timothy and Cynthia Shanahan argue that “disciplinary literacy” — advanced literacy instruction embedded within content-area classes such as math, science, and social studies — should be a focus of middle and secondary school settings. Moving beyond the oft-cited “every teacher a teacher of reading” philosophy that has historically frustrated secondary content-area teachers, the Shanahans present data collected during the first two years of a study on disciplinary literacy that reveal how content experts and secondary content teachers read disciplinary texts, make use of comprehension strategies, and subsequently teach those strategies to adolescent readers. Preliminary findings suggest that experts from math, chemistry, and history read their respective texts quite differently; consequently, both the content-area experts and secondary teachers in this study recommend different comprehension strategies for work with adolescents. This study not only has implications for which comprehension strategies might best fit particular disciplinary reading tasks, but also suggests how students may be best prepared for the reading, writing, and thinking required by advanced disciplinary coursework.

Reading is commonly viewed as a basic set of skills, widely adaptable and applicable to all kinds of texts and reading situations. Accordingly, in the 1990s, most states took on the challenge of improving young children’s reading skills, assuming that once the basics of literacy were accomplished, students would be well equipped for literacy-related tasks later in life (Blair, 1999). The idea that basic reading skills automatically evolve into more advanced reading skills, and that these basic skills are highly generalizable and adaptable, is partially correct: The basic perceptual and decoding skills that are connected with early

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literacy learning (e.g., phonics, phonological awareness, sight vocabulary) are entailed in virtually all reading tasks (Rayner & Pollatsek, 1994).

However, as one moves along the continuum of literacy learning, what is learned becomes less generally useful. Take one very simple example: Children in kindergarten and first grade may learn to read words like *of*, *is*, and *the*. These words are ubiquitous; they appear not only in primers but in the *New York Times*, U.S. State Department documents, medical books, and so on. As learning progresses, instruction necessarily focuses attention on words in more constrained and specific contexts. For example, it is beneficial to be able to pronounce and interpret words like *paradigm*, *rhombus*, *esoteric*, and *reluctant*, but these words have relatively less general applicability (e.g., *rhombus* may only appear in math books, and *esoteric* is rarely included in primary school texts and only shows up occasionally after that).

The Need for Advanced Literacy Instruction

We have spent a century of education beholden to this generalist notion of literacy learning — the idea that if we just provide adequate basic skills, from that point forward kids with adequate background knowledge will be able to read anything successfully. That view once seemed feasible because, following it, schools were able to produce a sufficiently educated population for the nation's economic needs. Although many students did not actually accomplish the highest, most specialized kinds of reading, there were enough to provide all of the chemists, accountants, engineers, and managers needed by the nation's economy. Those who developed more sophisticated reading skills with a minimum of later instructional support moved into jobs that required greater amounts of literacy, and those who did not extend their literacy skills worked in blue-collar jobs. A kind of stasis existed. Literacy was somewhat correlated with income, but there were high-literacy jobs that were low paying (e.g., teaching, secretarial work) and low-literacy ones that provided higher wages (e.g., auto assembly).

During the past generation, the expansion of information-based technology, the internationalization of labor markets, and the changing of workplace demands have increased the importance of literacy as an ingredient of economic and social participation (Carnevale, 1991). Increasingly U.S. jobs — even the shrinking pool of blue-collar jobs — require and depend upon reading. A generation ago, jobs in factories, foundries, and mills commonly required no reading, and many other jobs (e.g., law enforcement, practical nursing, trucking) required reading in limited amounts, but this has changed. The rising correlation between education and income is evidence of the increasing literacy orientation of many workplaces (Arc, Phillips, & McKenzie, 2000; Barton & Jenkins, 1995). Likewise, literacy is now clearly implicated in health maintenance (Berkman, DeWalt, Pignone, Sheridan, Lohr, Lux, et al., 2004), academic success (American College Testing, 2006), avoidance of the crimi-

nal justice system (Beck & Harrison, 2001), and social and civic involvement (Kirsch, Jungeblut, & Jenkins, 1993), including voting and keeping informed of public issues (Venezky, Kaestle, & Sum, 1987).

Despite the growing need for literacy, especially higher-level literacy skills, assessment data suggest that adolescents today read no better, and perhaps marginally worse, than a generation ago. According to the most recent National Assessment of Educational Progress (NAEP) (Grigg, Donahue, & Dion, 2007), high school students are scoring lower in reading now than they did in 1992. Fewer high school students are reading at proficient levels, and markedly more are reading at below-basic levels. Reading scores for U.S. eighth graders stayed steady during that period (Perle, Grigg, & Donahue, 2005), but only about 70 percent of students who enter eighth grade in the United States even complete high school (Frost, 2003). According to American College Testing (2006), the proportion of students on track for successful college work actually diminishes as students advance through U.S. schools from eighth through twelfth grade.

The most recent international data are no more reassuring than the national test scores (Kirsch, de Jong, Lafontaine, McQueen, Mendelovits, & Monseur, 2002). The Programme for International Assessment (PISA) is a standardized assessment designed specifically to compare student achievement across international boundaries. This evaluation reveals that American 15-year-olds do not perform as well in reading as their age-matched peers in fourteen other countries: Australia, Austria, Belgium, Canada, Finland, France, Iceland, Ireland, Japan, Korea, New Zealand, Norway, Sweden, and the United Kingdom. The students in most of these countries perform better than U.S. students on all of the various reading scales. Meanwhile, American high school students cannot read at the level necessary to compete in a global economy, and many are likely to have difficulties in taking care of their health needs (Berkman et al., 2004) or participating in civic life (Kirsch et al., 1993; Venezky et al., 1987).

In the 1990s, recognizing that U.S. schools were no longer producing enough highly educated students who could participate in jobs that required reading, various state and federal programs were initiated to improve reading achievement among young children. Within the scope of the standards movement in education, many state governors declared third-grade reading attainment to be the goal, and a plethora of new programs and initiatives emerged, including, at the federal level, the Reading Excellence Act (which, among other things, rewarded states for upgrading their reading preparation standards for primary-grade teachers), Early Reading First, and the now-beleaguered Reading First (U.S. Department of Education, 2007). Publishers responded with new upgraded curricular materials and assessments targeting the reading needs of young children, and early interventions for unsuccessful beginners (such as Reading Recovery) became commonplace in the schools. These extensive (and expensive) efforts have apparently been successful, as national reading scores for young children have climbed since 1992, and growth has been apparent in both NAEP test scores and trend items (Perle et

al., 2005; Perle & Moran, 2005). America's nine-year-olds are reading markedly better by all measures than they were fifteen years ago.

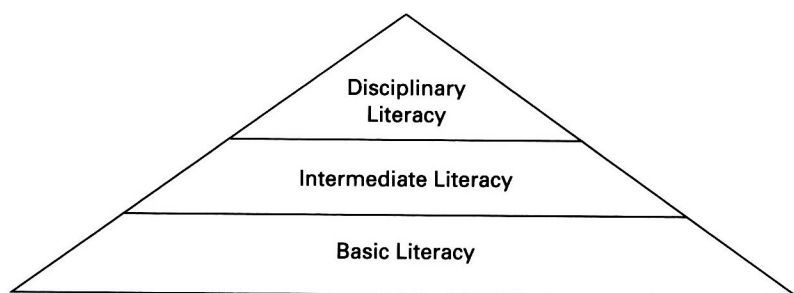
However, the idea that early literacy improvement would automatically lead to consequent later growth in literacy has not panned out. Early learning gains, instead of catapulting students toward continued literacy advancement, disappear by the time these students reach eighth grade (Perle et al., 2005). The idea that enhanced early teaching practices will continue to provide literacy advantages without continued enhanced teaching efforts — the so-called “vaccination” conception of teaching (Shanahan & Barr, 1995, p. 982) — does not appear to hold. Apparently, strong early reading skills do not automatically develop into more complex skills that enable students to deal with the specialized and sophisticated reading of literature, science, history, and mathematics (Perle et al., 2005). Most students need explicit teaching of sophisticated genres, specialized language conventions, disciplinary norms of precision and accuracy, and higher-level interpretive processes. Simply put, sound later-reading instruction needs to be built on a solid foundation of sound early-reading instruction if students are going to reach literacy levels that enable them to compete for the most lucrative jobs in the U.S. economy. Sixty-five thousand immigrant workers enter the United States each year in order to make up for the shortfall in availability of managers, engineers, analysts, and other high-education/high-salary positions, and there is continued pressure to increase these numbers (Levy & Murnane, 2004; Mitchell, Carnes, & Mendosa, 2006).

Given these gaps, there is a clear need to expand literacy instruction upward through the grades and to better support the reading of older students. But how can that best be accomplished? One possibility would be to focus mainly on extending basic literacy instruction upward for the lowest-achieving adolescents. However, a consideration of the new demands for literacy (Levy & Murnane, 2004) would suggest that there is a growing need for more sophisticated literacy development, and not just for the lowest achievers. Thus, there is a need to identify what a more advanced literacy curriculum might be and to determine how it could best be implemented. The remainder of this article will describe a Carnegie-funded research project that is identifying sophisticated, high school-appropriate literacy skills and exploring how to implement them within teacher-preparation programs.

A Model of Literacy Progression

The pyramid in Figure 1 illustrates our perspective on how the development of literacy progresses. The base of the pyramid represents the highly generalizable basic skills that are entailed in all or most reading tasks. These skills include basic decoding skills, understanding of various print and literacy conventions (e.g., understanding that text must be meaningful, the primacy of print versus illustrations, directionality, concept of word), recognition of high-frequency words, and some basic fluency routines (e.g., responding appro-

FIGURE 1 *The Increasing Specialization of Literacy Development*



Basic Literacy: Literacy skills such as decoding and knowledge of high-frequency words that underlie virtually all reading tasks.

Intermediate Literacy: Literacy skills common to many tasks, including generic comprehension strategies, common word meanings, and basic fluency.

Disciplinary Literacy: Literacy skills specialized to history, science, mathematics, literature, or other subject matter.

priately to basic punctuation). Students also come to expect certain organizational or structural properties in texts, such as the basic problem-centered formulation of stories or the list structure in simple expository texts, and they come to assume the presence of an author, though their conception of *author* is not particularly rhetorical, intentional, or separate from the reader's own perspective (Shanahan, 1992, 1998). Most children master these kinds of basic reading skills and conventions during the primary grades, and even those slow to develop tend to master all of these skills before high school entry.

As students go beyond these basic aspects of literacy, usually by the upper elementary grades, they begin to add more sophisticated routines and responses to their reading repertoires. These more sophisticated responses are not as widely applicable to different texts and reading situations, but nor are they particularly linked to disciplinary specializations. Students develop the skills that allow them to decode multisyllabic words quickly and easily, and they learn to respond with automaticity to words that do not appear with high frequency in text. They also learn to interpret and respond appropriately to less common forms of punctuation (e.g., split quotes, commas in a series, colons) and to know the meanings of a larger corpus of vocabulary terms, including many words that are not common in oral language (though again, these are not necessarily the highly specialized and technical terminologies of the disciplines).

Various reading comprehension responses and strategies come into play as well. For example, students develop the cognitive endurance to maintain attention to more extended discourse, to monitor their own comprehension, and to use various fix-up procedures if comprehension is not occurring (e.g.,

rereading, requesting help, looking words up in the dictionary). Students also gain access to more complex forms of text organization (e.g., parallel plots, circular plots, problem-solution, cause-effect), and begin to use author intention as a general tool for critical response (that is, they start to infer author purpose and to consider the implications of the choices that emanate from such a purpose). The majority of American students gain control of these intermediate reading tools by the end of middle school, but it is common to find high school students who still struggle to read texts because they have not mastered those tools.

Finally, during middle school and high school, many students begin to master even more specialized reading routines and language uses, and these particular outcomes, although powerful and valuable, are also more constrained in their applicability to most reading tasks. The constraints on the generalizability of literacy skills for more advanced readers — symbolized here by the narrowing of the pyramid — are imposed by the increasingly disciplinary and technical turn in the nature of literacy tasks. A high school student who can do a reasonably good job of reading a story in an English class might not be able to make much sense of biology or algebra books, and vice versa. Although most students manage to master basic and even intermediate literacy skills, many never gain proficiency with the more advanced skills that would enable them to read challenging texts in science, history, literature, mathematics, or technology (Grigg et al., 2007; Kutner, Greenberg, Jin, Boyle, Hsu, & Dunleavy, 2007).

In literacy development, progressing higher in the pyramid means learning more sophisticated but less generalizable skills and routines. The high-level skills and abilities embedded in these disciplinary or technical uses of literacy are probably not particularly easy to learn, since they are not likely to have many parallels in oral language use, and they have to be applied to difficult texts. (The difficulty of texts may arise from high levels of abstraction, ambiguity, and subtlety, or from content that differs from, or even contradicts, students' life experiences. For example, physics texts might explore conceptions of how objects fall that are inconsistent with how most individuals conceptualize such phenomena.) But something else makes these high-level skills very difficult to learn: They are rarely taught. By the time adolescent students are being challenged by disciplinary texts, literacy instruction often has evaporated altogether or has degenerated into a reiteration of general reading strategies (the general study skills that have usually been the mainstay of "content-area reading") — most likely to benefit only the lowest-functioning students (Bereiter & Bird, 1985). Given the range of student abilities and the difficulty of learning these more sophisticated routines, is it any wonder so many teachers fail to teach these aspects of literacy at all (Alvermann, O'Brien, & Dillon, 1990; Pressley, 2004)?

The pyramid illustrates the increasing specialization of reading skills, but a similar structure could be used to accurately illustrate the declining amount of

instructional support and assistance that is usually provided to students as they progress through the grades. Given the common belief that literacy skills are fully developed in the early grades, we would expect less literacy instruction in the upper grades — the vaccination model. However, there are also many institutional barriers that prevent the delivery of effective reading instruction in the middle and high school grades. Table 1 summarizes some of the differences between elementary and secondary school literacy instruction and context, and it reveals a much greater infrastructure of social and material support for reading instruction for younger students than for older ones.

Addressing the Need

Obviously, there are many barriers to successfully addressing the nation's literacy needs among adolescents, perhaps none more important than the preparation of a teaching force capable of delivering the needed instruction. To that end, the Carnegie Corporation recently began funding a network of pre-service teacher-education projects. These projects require several teacher-preparation institutions across the country to identify effective practices for teaching adolescent literacy and to develop course curricula that would help prospective teachers integrate literacy instruction into the content domains. These individual projects are quite diverse in their approaches to these issues (for more information on this effort, see www.carnegie.org/literacy/initiative.html). Our Carnegie project has challenged us to rethink the basic curriculum of adolescent literacy instruction, particularly with regard to reading comprehension strategy instruction within the disciplines. Specifically, we spent the first year of our project working with specialists in mathematics, chemistry, and history to identify sophisticated and appropriate reading skills that would better enable students to progress in these subject areas, and then, using that information, we began studying how to help students learn these skills. We spent the second year of the project attempting to implement these new strategies in urban high schools and in our secondary teacher-preparation programs.

One of the requirements of the initiative was to involve members of the arts and sciences in these efforts to rethink our response to adolescent literacy. We accomplished this task by creating teams for each of three disciplines: chemistry, history, and mathematics. The teams included two "disciplinary experts," university professors who were researchers in their discipline; two teacher educators who prepared teachers to teach that discipline in high school; two high school teachers who taught disciplinary content to students at diverse schools in and around Chicago; and two literacy experts (us). This research design reflected our assumption that teachers in the disciplines resist literacy strategy instruction when that instruction is promulgated by individuals who are literacy experts without particular content knowledge (O'Brien, Stuart, & Moje, 1995). Acknowledging the limitations of our disciplinary knowledge, we

TABLE 1 *Institutional and Contextual Differences in Elementary School and Middle/High School Literacy Instruction*

	<i>Elementary School Literacy</i>	<i>Middle/High School Literacy</i>
Teacher Literacy Preparation	Extensive certification standards often requiring multiple courses in reading (Darling-Hammond, 1999)	Limited certification standards usually not linked to specific grade level or content standards; often no course requirements at all (Barry, 1994)
Student Learning Standards	Grade-specific learning standards for reading in all 50 states (U.S. Department of Education, 2005)	Almost no grade-specific or subject-specific reading standards (American College Testing, 2006)
Federal Support for Reading Instruction	Reading First (\$5 billion)	Striving Readers (\$30 million)
Screening and Monitoring Assessments for Guiding Instruction	DIBELS, PALS, TPRI, etc.	None
Reading Textbooks and Instructional Materials Aimed at Improving Reading	Extensive numbers of core, supplemental, and intervention programs	Severely limited (though growing) numbers of commercial programs — mainly intervention programs aimed at low-achieving readers (Deshler, Palincsar, Biancarosa, & Nair, 2007)
Organization of Instruction	Mainly self-contained classrooms that permit intensive and extensive literacy instruction Extensive reading supports offered to low-achieving readers, including in-class and pull-out interventions	Departmentalized teaching that limits the possibility of extended literacy instruction Severely limited instructional interventions to support struggling readers
Parent Involvement	Great amount of parent awareness, involvement, and extensive ability to help their children develop literacy	Limited parent awareness of literacy development, limited involvement in helping their children with academic learning

were willing to rethink traditional reading comprehension strategy instruction based on the insights we could draw from these content specialists.

We also entered this study with a particular notion of “disciplinary knowledge.” We believe, along with a number of linguists and cognitive scientists (Bazerman, 1998; Fang, 2004; Geisler, 1994; Halliday, 1998; Schlepppegrell,

2004), that although the disciplines share certain commonalities in their use of academic language (Snow, 1987), they also engage in unique practices. That is, there are differences in how the disciplines create, disseminate, and evaluate knowledge, and these differences are instantiated in their use of language.

There are at least three views regarding why this is so. One view is that the various disciplines — ostensibly to protect the public from “charlatans” but really to preserve a power base — created professional organizations with standards and distinct ways of expressing themselves (Geisler, 1994). Others reject that view, claiming instead that the differences are a natural outgrowth of differences in the nature or kind of knowledge being created by the disciplines (Schlepppegrell, 2004). Still others argue that these differences are more a reflection of the *activities* in which the disciplines find themselves engaged (Bazerman, 1998). These activities include struggles for power, alliances, theoretical shifts, the creation of new forms of knowledge, and so on, which converge in acts of written communication. Together these positions are persuasive that the function of discipline-based texts is both ideational and social. Texts serve to advance knowledge while at the same time serving to maintain a field’s hegemony. The end result is that the literacy demands on students are unique, depending on the discipline they are studying.

Since we initially needed to identify the specialized reading skills and demands within the disciplines, we spent the entire first year of the Carnegie project immersed in discovering how each of these disciplines used literacy, employing several procedures to help us work toward that sometimes-elusive goal. We brought each panel together and had the panel members read various documents (e.g., textbooks, articles, web pages) for the purpose of learning how they approached reading and what they saw as the challenges to students. To guide discussions about student difficulties, we provided the teams with a literacy framework that included the dimensions of vocabulary, comprehension, fluency, and writing and asked them to identify the challenges in each dimension that students faced while reading discipline-based texts.

We also asked the disciplinary experts to read and think aloud about their own reading processes. In separate meetings, each of the experts read and thought aloud about a text that we provided (one that could be used by a high school student) and a text they were currently reading in their profession (the mathematicians chose articles, the chemists chose articles and trade magazines, and the historians chose books). We taped and transcribed these think-alouds and took both the protocols and a summary to the disciplinary-group meetings, where we discussed the results. From those think-aloud discussions, we distilled a list of “reading facilitators” that the discipline experts used as they read. We also introduced the concept of *strategy* to the teams, showed them some commonly used “across the content area” strategies that are often taught in reading courses, and asked them for a critique. In addition, we charged the teams with proposing strategies that they thought could

help students learn from their texts. These newly proposed strategies were then critiqued by the groups.

The other major goal of the project was to see if we could implement these strategies successfully with high school students and train beginning teachers to teach these strategies to their students. The high school teachers on our panels spent the second year pilot-testing some of these strategies in their classrooms — those that the groups believed would be most helpful. We observed and videotaped these teachers as they engaged in this teaching, later showing the videotapes to the team for their insights on how the strategies might be strengthened. These teachers also reported back to the disciplinary groups and shared the students' products that emerged from the lessons they taught. We used those pilot tests to identify potentially useful strategies for more rigorous later study. We also involved students who were enrolled in a teacher-preparation course for middle and high school literacy teaching in observation of these teachers and provided them with information about the project. Now we are revising that course to ensure that the literacy in the disciplines is more accurately and appropriately represented and that the preservice teachers learn strategies more specific to the specialized needs of their discipline.

Lessons Learned in the First Year

The first year of the project allowed a specification of how deeply different the disciplines are. Each of the disciplinary experts emphasized a different array of reading processes, suggesting the focused and highly specialized nature of literacy at these levels. For example, during think-alouds, the mathematicians emphasized rereading and close reading as two of their most important strategies. One of the mathematicians explained that, unlike other fields, even "function" words were important. "'The' has a very different meaning than 'a,'" he explained. Students often attempt to read mathematics texts for the gist or general idea, but this kind of text cannot be appropriately understood without close reading. Math reading requires a precision of meaning, and each word must be understood specifically in service to that particular meaning. In fact, the other mathematician noted that it sometimes took years of rereading for him to completely understand a particular proof.

The chemists were most interested in the transformation of information from one form to another. That is, when reading prose, they were visualizing, writing down formulas, or, if a diagram or a chart were on the page, going back and forth between the graph and the chart. One chemist explained, "They give you the structure, the structure of the sensor is given, so I was looking at the picture as I was reading and I tried to relate what was in the picture to what they were saying about how mercury binds to one part of the molecule." This explanation, corroborated by the chemists' other comments, helped us understand that in chemistry, different or alternative representations (e.g.,

pictures, graphs or charts, text, or diagrams) of an idea are essential for a full understanding of the concepts. These various representations are processed recursively as reading progresses.

The historians, on the other hand, emphasized paying attention to the author or source when reading any text. That is, before reading, they would consider who the authors of the texts were and what their biases might be. Their purpose during the reading seemed to be to figure out what story a particular author wanted to tell; in other words, they were keenly aware that they were reading an interpretation of historical events and not "Truth." Note what one historian said when reading a text about Abraham Lincoln: "I saw, oh . . . I don't know him [the author] very well, but he is part of a right-wing group of southern conservatives who is a secessionist. I'm not sure that the best model for thinking about Lincoln as a president is one that comes from a racist. So I have my critical eyes up a little bit, so it's a bit of a stretch to be friendly to, so I wanted to make sure to read it fairly."

In this nuanced example, the historian is revealing that he does not read the text as truth, but rather as an interpretation that has to be judged based on its credibility. He attempts to evaluate its credibility through an examination of the author's biases. Knowing that the author belongs to a right-wing southern secessionist group, the historian understands that any criticism of Abraham Lincoln's role in the Civil War may be fueled by this right-wing stance. However, he also knows that he, as a reader, has his own biases, and that his disregard for right-wing secessionist groups might color his reading to the point that he could miss important insights. The point is that he reads with a view in which both author and reader are fallible and positioned.

We have come to believe that the varied emphases shown in these examples are related to the intellectual values of a discipline and the methods by which scholarship is created in each of the fields. History relies heavily on document analysis (*document* being widely defined to include film, interview protocol, primary, secondary, or tertiary documents, and so on). These documents are collected after an event has occurred, and the selection and analysis of documents take place somewhat simultaneously. Thus, it is possible for a historian to choose and analyze evidence, unwittingly perhaps, that corroborates a previously held perspective. The historians we studied read with that caution in mind. Unfortunately, the nature of historiography (that is, how history is written and presented) is not often the subject of discussion in adolescent history classes. Students believe that they are reading to learn "the facts" and fail to take into account potential bias unless they are explicitly taught to do so (Hynd-Shanahan, Holschuh, & Hubbard, 2005).

Unlike historians, chemists create knowledge through experimentation. The findings of experiments are somewhat dependent upon the quality of the instrumentation, the design, and the statistical analysis. However, these variables are all decided on prior to the actual experiment. The findings are generalizable to other experiments under the same conditions. Although chem-

ists are not uncritical readers, we found that the chemists we studied did have more confidence than historians in the utility of the knowledge that had been created; they believed they could use that knowledge to predict what would happen under similar conditions. What was important to them in reading, consequently, was a full understanding of the way an experiment took place and the processes it uncovered. Gaining that full understanding required them to think about the phenomenon being presented in prose, to visualize it, and to manipulate it in formulas and equations.

The mathematicians we studied were theoretical rather than applied mathematicians. In their field, errorless proofs are by their very nature true, and the purpose of their work is to create these proofs; hence, to create truth. Because proofs must be error free, they are read carefully in order to discover any possible error. Every word matters. Rereading is essential. One mathematician said, "I try to determine whether it [the solution to the problem] is correct. That's the important criteria, and it's by no means assumed. It would be unusual to read a paper like this and not find something incorrect." This mathematician is illustrating the belief that truth (correctness within the confines of a particular problem) is attainable if one can determine an error-free solution. However, errors are easy to make, so vigilance is required.

In summary, the disciplinary experts we studied approached reading in very different ways, consonant with the norms and expectations of their particular disciplines. We left this phase of the study convinced that the nature of the disciplines is something that must be communicated to adolescents, along with the ways in which experts approach the reading of text. Students' text comprehension, we believe, benefits when students learn to approach different texts with different lenses. There is evidence to suggest that this is true. Studies attempting to teach history students to "read like historians" have found that students who are taught to use the approaches that historians use when they read (to evaluate the source and context of the textual information and corroborate it with other texts) learn to think more critically about what they read (Hynd-Shanahan et al., 2005; VanSledright & Kelly, 1998), and to write better essays (De La Paz, 2005), although they do not necessarily end up with more historical information (Nokes, Dole, & Hacker, 2007). Studies of adolescent students' science writing have found writing improvement when teachers show students how to write for different purposes (e.g., to describe, to persuade) and how to use different structures (e.g., research articles, lay explanations, patent applications, lab notes) for scientific writing (Hand & Prain, 2002).

In addition to studying the processes that experts used as they read, we also studied the team members' perceptions of the literacy challenges that students face as they read — and learn to read — disciplinary texts. As stated earlier, we provided the teams with a framework that included four literacy components: vocabulary, comprehension, fluency, and writing. We explained and demonstrated what these components are, requested that the team read various texts used in high schools, and asked for their thoughts about the problems stu-

dents would have when confronted with such materials. Not only did the three teams approach reading in different ways, they also had unique ideas about the challenges students would face regarding each of the components.

Regarding vocabulary, for example, the mathematicians and chemists alike noted the challenge of words that had both general and specific meanings. However, unlike the chemists, the mathematicians were adamant that the precise mathematical definition needed to be learned — memorized, as it were — in order to obtain true understanding of the mathematical meaning in contrast to its more general meaning. For example, a student must know that *prime* refers to a *positive integer not divisible by another positive integer (without a remainder) except by itself and by 1*. Prime also means *perfect, chief, or of the highest grade*, but none of these nonmathematical meanings aids in understanding the mathematical meaning. In contrast, the historians did not even mention words with both general and specific meanings. Rather, they noted that although history did not have as much technical vocabulary as other fields, technical terminology was often co-opted from fields such as political science, economics, and sociology. In addition, the historians noted that the difficulty level of the general vocabulary could be quite high. Terms such as *aggressive* or *adversarial* are difficult, yet their meaning is not necessarily specific to history. They also mentioned that students often had to read and understand words that are not current (e.g., the Gilded Age) or that need to be understood metaphorically (e.g., Black Thursday).

The mathematicians also emphasized that letters and symbols signify specific meanings in some cases but, as variables, change their meaning in others. Being able to read these symbols embedded in both English prose and algebraic equations was considered to be crucial. For instance, when one of the mathematicians was thinking aloud during the reading of a journal article, he explained that one of the first things he did when reading was to memorize the variables that were to be used in the rest of the article. Even though the article began as mostly prose, he would soon be reading only symbols, and he did not want to interrupt his flow of thought by having to return to the definitions. Further complicating the use of symbols, the chemists noted that symbols needed to be understood at both macro and micro levels. For example, each symbol on the atomic chart must be thought of not only in terms of the substance it describes, but also in terms of its atomic makeup. That is, H_2O is not just the symbol for *water* in the same way that n is the symbol for *number*; H_2O also specifies that there are two atoms of hydrogen for every atom of oxygen.

Linguists have studied the differences in social science and science texts, and their studies corroborate these findings. A characteristic of academic language, for instance, is *nominalization* — the transformation of a verb to a noun (Halliday & Martin, 1993; Martin, 1993). In science texts, nominalization is used to create technical vocabulary. For example, rather than write “salt dissolved,” a scientist might write “salt goes through a process of dissolution.” Nominalization serves to move a phenomenon from the particular or spe-

cific to the abstract or general. The term *dissolution* can be used to describe the process that occurs with a variety of substances, and it should be learned apart from its association with salt. The meaning of *dissolution* as it is used in chemistry is quite specific and very different from its other meanings, two of which are "indulgence in sensual pleasures; debauchery" and "extinction of life: death" (Pickett, 2000). Although the specificity of technical definitions was mentioned by the chemists with whom we talked, nominalization was not. Nevertheless, the phenomenon does have implications for high school chemistry students. The abstract language that is used in chemistry texts is daunting for many high school students because it makes the subject matter more distant and disconnected from everyday experiences.

In history texts, nominalization and the resulting abstraction do exist, but these occur most frequently with general terms (Schleppegrell, 2004). Note the following hypothetical example to illustrate this point:

The enlargement of the nation's capacity to produce weapons, the advent of the aeroplane, and the improvement in worldwide communication systems through the telegraph increased the likelihood that the United States would enter the war.

In this example, the events are nominalized as subjects of the sentence and are buried in the clauses. The process, *increased*, is realized as the verb. Even without technical vocabulary, this sentence is difficult. An expert knows after reading the sentence that the United States produced weapons, developed a viable airplane, and utilized the telegraph to communicate with other countries, but that is not the point of the sentence. In addition, the arcane spelling of *aeroplane* may reflect the time period described but it is likely unknown to many students. History texts, then, present challenges to readers that are qualitatively different from those presented by texts in other disciplines.

Science texts have a high degree of lexical density, higher than that of either mathematics or history. *Lexical density* is marked by the number of content words embedded in clauses, by the total number of content words, or through the percentage of content words in relation to the total number of words (Fang, 2004). These content words are technical terms, which must be deeply learned in order to learn the science behind them. For example, biology students must not only know that *digestion* is the assimilation of food in the body, but also understand the process by which digestion occurs.

The differences among the texts of different disciplines result in unique challenges for readers. These text differences, however, are not often within the purview of literacy courses in teacher-preparation institutions, nor are they the subject of discipline-based methods course work; for that matter, they are not usually discussed in the basic content courses teachers take within their discipline. As a result, teachers are not prepared to address the challenges posed by the special demands of texts across the various disciplines. Yet, adolescent students engage in a daily struggle to learn the content of the various

disciplines — content that is instantiated in the academic discourse that is an outgrowth of the differences in the disciplines themselves.

Thus, the first year of the study helped us to understand the special literacy demands presented by the different disciplines. The interviews, discussions, analytic tasks, and informal conversations revealed three very different approaches to reading that drew on the ways these disciplines create, communicate, and evaluate knowledge.

Lessons Learned in the Second Year

In the second year of our study, we focused on the creation of discipline-specific strategies. This work was challenging. Every member of each team seemed fully fascinated by the key role of literacy in their own lives and in the lives of high school students learning disciplinary concepts, and they could clearly discuss the unique challenges that students faced as they read texts within their discipline. However, the experts, and in some cases the teacher educators and high school teachers, displayed some reluctance in embracing the idea of strategy instruction. For most the concept was new, and the content-area reading strategies we shared with them may have seemed a little contrived. Thus, our introduction to strategy instruction in the team meetings fell somewhat flat, except in history, where one of the high school teachers was “a strategy nut” (a title given to him by one of the disciplinary experts). This reluctance was revealing to us because it mirrored the disinclination of the preservice students in the high school literacy class.

The chemistry team’s reluctance only changed when we introduced our version of structured note-taking or structured summarization, a strategy that we based specifically on their insights about chemistry reading. Using this strategy, students are required to take notes in a chart format. Each section of the chart reflected the information that these chemistry specialists indicated would comprise an essential reading of chemistry texts. That is, because chemistry is about the properties of substances and their reactions, a reader who paid attention to these elements would be engaging in a disciplinary-focused reading. Thus, the chart required students to summarize substances, properties, processes, and interactions. We had illustrated the chart using information from one of the chemistry textbooks the team members had shared with us. One of the chemists who had been somewhat dismissive of teaching traditional content-area reading strategies (such as summarization) in chemistry classes reacted by saying, “Well, if they used this, they would be learning chemistry.” He then suggested a modification (the inclusion of a place to summarize atomic expression). Evidently, the difference between this strategy and a strategy like summarization was its subject-matter specificity. This strategy was not just about understanding text; it was also about understanding the essence of chemistry.

This structured-summarization strategy meshed well with concerns the chemists had expressed earlier when they examined high school chemistry

textbooks: the need to identify where the chemistry was. That is, although they understood that some of the information in the text was included purely for motivational purposes or to establish context for students, they were concerned that what students were actually supposed to learn about chemistry was obscured and hidden by these devices. One of the chemistry teachers bitterly complained about a text she had to use in which each chapter began with a real-life problem (such as lake pollution) that was then followed by an explanation of the chemistry behind the problem. She complained that the students were not learning the chemistry. Chemistry learning is somewhat hierarchical in nature. The concepts build on each other, and these concepts can then be applied to situations. That is, the principles are taught as abstractions and the particulars are exemplars of the abstractions. This chemistry book, however, perseverated on the particular, providing students with little real opportunity to learn the abstractions that could be used to solve other problems.

Mathematicians revealed a similar concern. They decried the presence of “extraneous” text in mathematics textbooks. As Solomon and O’Neill (1998) explain, mathematicians make fairly clear distinctions between the complementary informal or introductory material in text that includes analogies, examples, motivations, and so on, and the formal structure of definitions, theorems, proofs, and explanations. The panelists were concerned that students would not be able to make those distinctions, and thus that the textbooks are made more difficult rather than easier by the inclusion of such devices.

In the mathematics team meeting, even the mathematics-specific strategies we generated garnered little enthusiasm. However, one of the mathematics teacher educators shared some of their preferred strategies with the group. One was a mathematics-structured note-taking strategy. In this strategy, students would write the mathematics “big idea” that was being studied in the first column. In the next column, they would write the explanation of the big idea, and in the following columns, they would provide an example, show a formula, make a graph or diagram, or otherwise illustrate the big idea. They were to complete this work as they were reading and then use it as a study guide prior to a unit test. The mathematicians wanted to make sure that if a concept was being defined, the precise mathematical definition would be used and the idea would be added to the chart.

In the history meetings, the team liked a number of strategies and made suggestions for improvement. One such strategy was the history events chart. As students read about a particular event, they write down answers to the questions of who, what, where, when, how, and why in order to summarize the key narrative events. They do the same with each event they read about. However, the compelling task — the one that addresses a specific disciplinary problem in reading history — is to determine what the relationship is between the first and second event, between the second and third event, and so on. Students are asked to think about the most likely connections and to write these on the

chart. The historians were approving of this task because it mirrored the kind of thinking that historians do. That is, historians infer cause-and-effect relationships when they study events and what precedes and follows them. These relationships are not necessarily visible in the events themselves, nor are they always made explicit in high school history texts, so they must be surmised. And, if they *are* made explicit in the text, students generally regard the connection as "truth" rather than as the construction of the writer. The task, then, not only mirrored historians' thinking but also offered the opportunity for students to construct the cause-and-effect relationships themselves.

At the time of this writing, the high school teachers have tried out several promising strategies in the classroom, including the ones described above. One of the history teachers engaged in a quasi-experimental study of another history strategy — one he called "the multiple-gist" strategy. In this strategy, students read one text and summarize it, read another text and incorporate that text into the summary, then read another text and incorporate that text into the summary, and so on. The summary has to stay the same length, essentially, and this forces a student to use words such as *similarly* or *in contrast* when incorporating texts that can be compared or contrasted with each other. His preliminary results reveal that students who learned the multiple-gist strategy wrote longer, more coherent answers to essay questions.

In summary, what we learned from the second year of the study was that the disciplinary teams advocated strategies that mirrored the kinds of thinking and analytic practices common to their discipline. While they politely acknowledged the value of more general strategies such as KWL (thinking about what you *know* and what you *want* to learn prior to reading, and what you *learned* after reading), they did not discuss using these strategies in teaching the content.

Conclusion

Literacy levels of adolescent students have languished in recent years, despite clear improvements in the reading performance of younger students. Although schools have managed to maintain the same levels of literacy attainment in the adolescent population that have been accomplished since the early 1970s, schools have not improved adolescent literacy levels since that time. This is unfortunate, as various social changes have increased the need for advanced literacy in America's economic, social, and civic life, and without increasing literacy attainment, many students are at risk of marginalization when they leave school.

Historically, instructional efforts in literacy have focused on highly generalizable skills and abilities, such as decoding, fluency, and basic comprehension strategies that can be applied to most texts and reading circumstances across the content areas. This is reasonable with younger children, but it becomes increasingly problematic as students advance through the grades because many

literacy skills and texts are highly specialized and require actions that are relatively unique. Traditional efforts to encourage every content-area teacher to be a reading teacher by pressing them to teach general-purpose strategies have neither been widely accepted by teachers in the disciplines nor particularly effective in raising reading achievement on a broad scale. More recent treatments and the data from this study suggest that as students move through school, reading and writing instruction should become increasingly disciplinary, reinforcing and supporting student performance with the kinds of texts and interpretive standards that are needed in the various disciplines or subjects.

This article describes a project that we undertook with Carnegie Corporation support. We began this project by asking how disciplinary experts approached reading and how those approaches might be translated into instruction for high school students. This project has helped us rethink the basic content-area literacy curriculum that needs to be taught to preservice teachers in secondary education, and it has revealed the benefits of having a conversation among disciplinary experts, literacy experts, high school teachers, and teacher educators. Instead of trying to convince disciplinary teachers of the value of general reading strategies developed by reading experts, we set out to see if we could formulate new strategies or jury-rig existing ones so that they would more directly and explicitly address the specific and highly specialized disciplinary reading demands of chemistry, history, and mathematics.

Formulating an appropriate curriculum for secondary teacher preparation is a necessary, though insufficient, condition for improving literacy teaching for middle and high school students. There is also a clear need for explicit literacy certification standards for teachers who teach in the disciplines, closer relationships between the faculties of education and the liberal arts and sciences (who too often separately prepare these teachers), and sufficient resources to allow preservice teachers to practice their teaching in varied disciplinary situations and classroom contexts. We believe the key to such changes, however, is a literacy curriculum that directly guides students to better meet the particular demands of reading and writing in the disciplines than has been provided by traditional conceptions of content-area reading.

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interests involve the intersection between the literacies and texts youth are asked to learn in the disciplines and those they engage with outside of school. She also studies how youth construct cultures and enact identities through their literacy practices outside of school. Moje is coeditor of the forthcoming *Handbook of Reading Research, Volume IV* (with P. D. Pearson, M. Kamil, and P. Afflerbach). Her other published volumes include *Reframing Sociocultural Research on Literacy: Identity, Agency, and Power* (coedited with C. J. Lewis and P. Enciso, 2007) and *All the Stories We Have: Adolescents' Insights on Literacy and Learning in Secondary School* (2000).

KAREN MORRIS is a doctoral candidate in the Joint Program in English and Education at the University of Michigan. Karen was a high school English and math teacher for four years before she returned to graduate school. Her academic areas of interest include grammar and writing instruction and standard language ideology.

MELANIE OVERBY is a postdoctoral fellow working on the Social and Cultural Influences on Adolescent Literacy Motivation and Development project at the University of Michigan. Her research interests include adolescent literacy, social identity formation and socialization, and literacy in informal learning environments. Overby's dissertation explored familial racial-ethnic socialization using narratives provided by cultural museums.

KRISTIE PORTER is a graduate student at the University of North Carolina at Chapel Hill, where she studies public health and specializes in survey design and implementation. Porter worked previously as a research associate at MPR Associates, where, among other projects, she analyzed the achievement gap between advantaged and disadvantaged students, evaluated a civics education curriculum, and managed data collection for the Broad Prize in Urban Education. Before joining MPR, she conducted health research and evaluation in middle schools as an education analyst at RTI International.

CYNTHIA SHANAHAN is a professor in the Department of Curriculum and Instruction at the College of Education, University of Illinois at Chicago, and executive director of the college's Council on Teacher Education. Her primary research focus is adolescent literacy, especially within content areas. As the principal investigator in a National Reading Research Center study, Shanahan examined the use of texts in learning science and history, culminating in her book, *Learning from Text across Conceptual Domains* (1998). She has taught literacy to underprepared college students for more than twenty years.

TIMOTHY SHANAHAN is a professor in the Department of Curriculum and Instruction at the College of Education, University of Illinois at Chicago, and director of the university's Center for Literacy. He has also served as the director of reading for the Chicago Public Schools and as the president of the International Reading Association. His research concentrates on reading achievement and assessment, family literacy, and reading-writing relationships. He is the editor of *Developing Reading and Writing in Second-Language Learners* (2008) and the developer of several instructional programs.

CATHERINE E. SNOW is the Henry Lee Shattuck Professor of Education at the Harvard Graduate School of Education. Her work focuses on literacy achievement among